INDOOR AIR QUALITY REASSESSMENT

Leicester Primary School
170 Paxton Street
Leicester, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Center for Environmental Health
Bureau of Environmental Health Assessment
Emergency Response/Indoor Air Quality Program
October 2004

Background/Introduction

At the request of Mr. Carl Wicklund, Facilities Manager, an indoor air quality assessment was conducted at the Leicester Primary School in Leicester, Massachusetts. This assessment was conducted by the Massachusetts Department of Public Health (MDPH), Center for Environmental Health's (CEH) Bureau of Environmental Health Assessment (BEHA). The report of odor of an undetermined origin in room 101 prompted this request.

On June 10, 2004, Michael Feeney, Director, Emergency Response/Indoor Air Quality (ER/IAQ), BEHA, visited the school to conduct a reassessment. Mr. Feeney was accompanied by Mr. Wicklund for portions of ths assessment.

The Leicester Primary School is a two-story brick building constructed in 1973-1974. The second floor consists mainly of general classrooms. The first floor contains general classrooms configured around a centrally located gymnasium and library. Windows are openable.

Actions on Recommendations Previously Made by MDPH

BEHA staff visited the building on January 10, 2001 and issued a report that made recommendations to improve indoor air quality (MDPH, 2001). A summary of actions taken on previous recommendations is included as Appendix A of this reassessment.

Methods

BEHA staff performed visual inspection of building materials for water damage and/or microbial growth. Air tests for carbon monoxide, carbon dioxide, temperature and relative humidity were conducted with the TSI, Q-Trak, IAQ Monitor, Model 8551. Air tests for airborne particle matter with a diameter less than 2.5 micrometers were taken with the TSI, DUSTTRAK™ Aerosol Monitor Model 8520. Screening for total volatile organic compounds (TVOCs) was conducted using a Thermo Environmental Instruments Inc., Model 580 Series Photo Ionization Detector (PID).

Results

This elementary school houses grades K-4, with a student population of 500 and a staff of approximately 63. The tests were taken under normal operating conditions. Test results appear in Table 1.

Discussion

Ventilation

It can be seen from table 1 that carbon dioxide levels measured were above 800 parts per million of air (ppm) in twelve of thirty-two areas surveyed indicating inadequate ventilation in some areas of the building. It is important to note, however, that some classrooms had open windows during the assessment or were sparsely occupied, which can greatly reduce carbon dioxide levels.

Fresh air in classrooms is supplied by a mechanical unit ventilator (univent) system (Figure 1). Univents were deactivated in a number of classrooms during the assessment. Mechanical exhaust ventilation in most classrooms is provided by ceiling-mounted intake grills connected to ductwork. As with the univents, exhaust vents were functioning throughout the building.

As previously recommended by the BEHA, both supply and exhaust ventilation should be operating continuously during school occupancy. In order to have proper ventilation with a univent and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. The ventilation system was reportedly balanced in 2001.

The Massachusetts Building Code requires a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week based on a time weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, please see Appendix A.

Temperature readings ranged from 72° F to 84° F, which were above the BEHA recommended range in some areas (primarily interior areas such as the library with no openable windows). The BEHA recommends that indoor air temperatures be maintained in a range of 70° F to 78° F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply.

The relative humidity in this building ranged from 45 to 61 percent, which was within the BEHA recommended comfort range in most areas evaluated. The BEHA recommends that indoor air relative humidity is comfortable in a range of 40 to 60 percent. Relative humidity in this building would be expected to drop below comfort levels during the heating season. The sensation of dryness and irritation is common in a low relative humidity environment Relative humidity levels in the building would be expected to drop during the winter months due to heating. It is important to note however, that relative humidity measured indoors exceeded outdoor measurements during air testing conducted when the building was occupied (range +3 to +19 percent). The increase in relative humidity during occupancy indicates that a contributing source of water vapor in this building is the occupants. Moisture removal is important since the sensation of heat conditions increases as relative humidity increases (the relationship between temperature and relative humidity is called the heat index). As indoor temperature rises, the addition of more relative humidity will make occupants feel hotter. If moisture is removed, the comfort of the individuals is increased. Removal of moisture from the air, however, can have some negative effects. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

One classroom had a water-damaged splashguard (Picture 1). Water-damaged particleboard can provide a source of mold and mildew and should be replaced.

Odor Investigation of Room 101

Mr. Wicklund reported that an odor was detected within Room 101 during the month of April 2004. Room 101 is located on the first floor of the northwest corner of the building. The north wall of this room contains a window system and univent. The west wall contains no window (Picture 2). Located in close proximity to the Room 101 wall system is an electrical transformer. Mr. Wicklund reported that the transformer had leaked insulating oil onto its slab and grass behind this unit. The contaminated soil was removed after the leak was discovered. Of note is that the removal of soil roughly coincides with the beginning of odor detection by staff in Room 101.

Mr. Wicklund reported extensive investigation of the univent interior to identify possible odors sources. Leicester school department staff could not identify a source of odors in the univent. The reported lack of odor in the univent was confirmed by Mr. Feeney during this assessment.

After examining Room 101 and interviewing a variety of Leicester School Department staff and faculty, *two* sources of odors appear to be contributing to the odor reports in this room. Odors reported by staff were described as a chemical-like, irritating, urine-like or musty. Based on this information, the following analysis identified the sink cabinet and the transformer oil remediation as the most likely sources of odors in Room 101.

Mr. Feeney detected a chemical-like, musty odor upon entering this room that was traced to a sink cabinet that had experienced water damage. The cabinet (Picture 3) was composed of plywood/particle board. Plywood is made using an adhesive that consists of urea-formaldehyde resin (US EPA and US CPSC, 1995). Under conditions of increased temperature and humidity indoors, the urea-formaldehyde resin can breakdown, releasing formaldehyde vapor. Formaldehyde is a volatile organic compound (VOC) that can cause irritation to the eyes, nose and throat. As the formaldehyde vapor evaporates, the other component of the resin, urea, remains in the particleboard. Urea has a urine-like odor, particularly detectable if it is mixed with water vapor. Mr. Wicklund agreed to remove this cabinet during the summer vacation.

While this odor was present in Room 101 during the assessment, some Leicester School Department staff and faculty reported a different odor, particularly in April around the timeframe of the transformer oil removal. Based on the timing of the reports of odor and removal of contaminated soil, the exterior of the Room 101 west wall was examined (Picture 4). Of note was the presence of large a hole in the brickwork at the slab/exterior wall junction, just above the remediated area (as identified by Mr. Wicklund). These openings are called weep holes. Exterior wall systems should be designed to prevent moisture penetration into the building interior. An exterior wall system should consist of an exterior curtain wall. Behind the curtain wall is an air space that allows for water to drain downward and for the exterior cladding system to dry. At the base of the curtain wall should be weep holes that allow for water drainage. Opposite the exterior wall and across the air space is a continuous, water-resistant material adhered to the back up wall that forms the drainage plane.

The purpose of the drainage plane is to prevent moisture that crosses the air space from penetrating into interior building systems. The plane also directs moisture downwards toward the weep holes. The drainage plane can consist of a number of water-resistant materials, such as tarpaper or, in newer buildings, plastic wraps. The drainage plane should be continuous. If the drainage plane is discontinuous, missing flashing or lacking air space, rainwater may accumulate inside the wall cavity and lead to moisture penetration into the building. Another problem with a discontinuous drainage plane is the possibility of *air* penetration through the wall system, particularly during subfreezing temperatures or wind impingement. In this situation, wind impingement most likely drove air into the wall system of Room 101 in April since the prevailing winds in Massachusetts tend to be from the west. Moist weather tends to travel in a northeasterly track up the Atlantic Coast towards New England (Trewartha, G.T., 1943). Wet weather systems generally produce south/southwesterly winds. Therefore, if the soil remediation were conducted under westerly wind conditions, odors from the soil could be directed toward the weep holes and into the wall cavity.

After making this determination, the interior of the Room 101 west wall was examined. The plastic coving along the wall was removed by Mr. Feeney. An opening in the seam between the wall and slab was identified (Pictures 6 and 7). In addition, present behind the coving were live insects. The presence of insects indicates that a breach exists in the wall drainage plane allowing insects to pass through the wall system. Thus, if insects can pass through this wall system, air and odors materials from outdoors can also gain entry into the Room 101 interior. Supporting this hypothesis is that the type of odor reported in this classroom abated once the remediation effort was completed.

Based on these observations, removal of the sink cabinet should remove the source of odor in this building, since the other odors ceased once the soil remediation was complete. Several actions to re-establish the wall vapor barrier would be necessary to prevent other odor and/or insect penetration into the building.

Other Concerns

Indoor air quality can also be negatively influenced by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants; however, the pollutant produced is dependent on the material combusted. Common combustion emissions include carbon monoxide, carbon dioxide, water vapor and smoke (fine airborne particle material). Of these materials, exposure to carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less (PM2.5) can produce immediate, acute health effects upon exposure. To determine whether combustion products were present in the school environment, BEHA staff obtained measurements for carbon monoxide and PM2.5.

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce immediate and acute health affects. According to the NAAQS established by the USEPA, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2000). Outdoor carbon monoxide concentrations were non-detectable or ND (Table 1). Carbon monoxide levels measured in the school were also ND. *Carbon monoxide should not be present in a typical, indoor environment*. If it *is* present, indoor carbon monoxide levels should be less than or equal to outdoor levels.

Several air quality standards have been established to address airborne pollutants and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within a rink, that operator must take actions of reduce carbon monoxide levels (MDPH, 1997).

ASHRAE has adopted the National Ambient-Air Quality Standards (NAAQS) as one set of criteria for assessing indoor air quality and monitoring of fresh air introduced by HVAC systems (ASHRAE, 1989). The NAAQS are standards established by the US EPA to protect the public health from 6 criteria pollutants, including carbon monoxide and particulate matter (US EPA, 2000). As recommended by ASHRAE, pollutant levels of fresh air introduced to a building should not exceed the NAAQS (ASHRAE, 1989). The NAAQS were adopted by reference in the Building Officials & Code Administrators

(BOCA) National Mechanical Code of 1993 (BOCA, 1993), which is now an HVAC standard included in the Massachusetts State Building Code (SBBRS, 1997).

As previously mentioned, the US EPA also established NAAQS for exposure to particulate matter. The NAAQS originally established exposure limits to particulate matter with a diameter of 10 μm or less (PM10). According to the NAAQS, PM10 levels should not exceed 150 microgram per cubic meter ($\mu g/m^3$) in a 24-hour average (US EPA, 2000). These standards were adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, US EPA proposed a more protective standard for fine airborne particles. This more stringent, PM2.5 standard requires outdoor air particle levels be maintained below 65 $\mu g/m^3$ over a 24-hour average (US EPA, 2000). Although both the ASHRAE standard and BOCA Code adopted the PM10 standard for evaluating air quality, BEHA uses the more protective proposed PM2.5 standard for evaluating airborne particulate matter concentrations in the indoor environment. Outdoor PM2.5 concentrations were measured at 3 $\mu g/m^3$ (Table 2). In most cases, PM2.5 levels measured in the school reflected outdoor levels and did not exceed the NAAQS.

Frequently, indoor air levels of particulates (including PM2.5) can be at higher levels than those measured outdoors. A number of mechanical devices and/or activities that occur in schools can generate particulate during normal operations. Sources of indoor airborne particulates may include but are not limited to particles generated during the operation of fan belts in window-mounted air conditioners, cooking in the cafeteria stoves and microwave ovens; use of photocopiers, fax machines and computer printing devices; operation of an ordinary vacuum cleaner and heavy foot traffic indoors.

Indoor air quality can also be negatively influenced by the presence of materials containing volatile organic compounds (VOCs). VOCs are carbon-containing substances that have the ability to evaporate at room temperature. Frequently, exposure to low levels of total VOCs (TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. For example, chemicals evaporating from a paint can stored at room temperature would most likely contain VOCs. In an effort to determine whether VOCs were present in the building, air monitoring for TVOCs was conducted. An outdoor air sample was taken for comparison. Outdoor TVOC concentrations were ND. Indoor TVOC concentrations were also ND with the exception of room 101. TVOC concentrations were ND in the center of the room, when TVOCs were measure in a sink cabinet, the TVOC concentrations ranged from 0.4 ppm to 2.5 ppm. The source of the measured TVOCs appeared to be a bag of treated wood shavings that is used by the custodial staff to absorb odors resulting from vomits. Custodial staff placed this bag in the cabinet to deodorize the cabinet. TVOC level dropped below detectable levels when the wood shavings were removed and the cabinet aired out.

As with the previous assessment, cleaning products continued to be found on counter-tops and beneath sinks in a few classrooms. Cleaning products contain chemicals that can be irritating to the eyes, nose and throat of sensitive individuals and should be kept out of the reach of students.

Also of note was the amount of materials stored inside classrooms. In classrooms throughout the school, items were seen piled on windowsills, tabletops, counters, bookcases and desks. The large amount of items stored in classrooms provides a means for dusts, dirt and other potential respiratory irritants to accumulate. Many of the items, (e.g., papers, folders, boxes, etc.) are tough to clean and make it difficult for custodial staff to clean around these areas. Dust can be irritating to the eyes, nose and respiratory tract. These items should be relocated and/or cleaned periodically to avoid excessive dust build up.

Conclusions/Recommendations

It appears that the odors reported in room 101 were transient in the case of the transformer oil leak and are expected to resolve completely once the sink cabinet is removed. In view of the findings at the time of the visit, in addition to those made in the previous report, the following recommendations are made to further improve indoor air quality:

1. Continue with plans to remove sink cabinet from room 101.
2. Seal the seam between the slab and interior wall in room 101 prevent air, odors and insect migration into the building.
3. Once the interior wall seal is repaired, have a mason repair cracks in the slab and insert screen/vent in weep holes that both prevent insect penetration and drain water.
4. Reduce the amount of items stored in classrooms to provide cleanable surfaces.
5. Store chemicals and cleaning products properly and out of the reach of students.
6. It is highly recommended that the principles of integrated pest management (IPM) be used to rid this building of pests. A copy of the IPM recommendations (MDFA, 1996) can be downloaded from the following website: http://www.state.ma.us/dfa/pesticides/publications/IPM_kit_for_bldg_mgrs.pdf.

7. For further building-wide evaluations and advice on maintaining public buildings, refer to the resource manual and other related indoor air quality documents located on the MDPH's website at http://www.state.ma.us/dph/beha/iaq/iaqhome.htm.

References

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Picture 1

A Water-Damaged Splashguard

Picture 2

Room 101 West Wall

Picture 3

Cabinet with Odor, Note Bag and Box Filled with Treated Wood Shavings

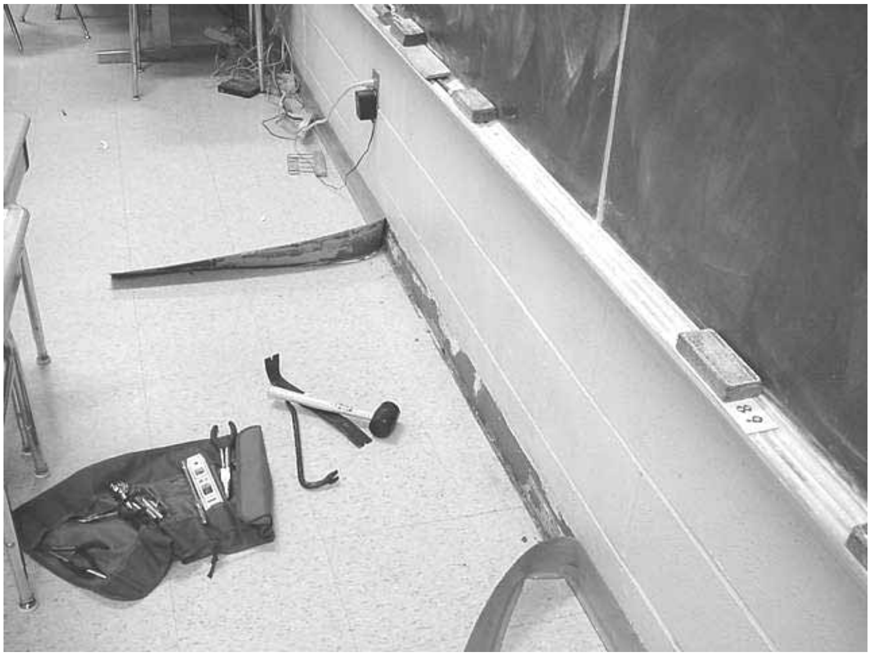
Picture 4

Area of Transformer Oil Removal

Picture 5

Weep Holes in West Wall of Room 101

Picture 6



Plastic Coving Removed from the Base of the Room 101 West Wall

Picture 7

Space in Seam of Floor/Wall in West Wall of Room 101

Leicester Primary School
170 Paxton Street Leicester, MA

Table 1

Indoor Air Results
June 10, 2004

Location/ Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (*ppm)	Carbon Monoxide (*ppm)	TVOCs (*ppm)	PM2.5 (µg/m3)	Occupants in Room	Windows Openable	Ventilation Supply	Ventilation Exhaust	Remarks
Background	73	42	380	ND	ND	3	-	-	-	-	Overcast AM Sunny PM
Library	80	48	790	ND	ND	8	2	-	Y Wall	Y Ceiling	PF, Laminator, Rubber Cement
Cafeteria	78	50	763	ND	ND	9	100+	Y 2/6 Open	Y Univent	Y	
Library Balcony	82	45	753	ND	ND	6	0	-	-	-	Cleaners, PF
101	78	54	1134	ND	ND	6	20	Y	Y Univent	Y	Y-2.5 ppm vocs from scented sawdust bags / canisters, plug-in
102	76	50	988	ND	ND	7	19	Y 1/3 Open	Y Univent	Y	Mushy, odor, carpet
103	75	53	956	ND	ND	4	20	Y 1/2 Open	Y Univent	Y	-
104	75	55	878	ND	ND	10	1	Y	Y Univent	Y Ceiling	CD

ppm = parts per million
µg/m3 = micrograms per cubic meter

AD = air deodorizer
AP = air purifier
aqua. = aquarium

AT = ajar ceiling tile
BD = backdraft
CD = chalk dust
CP = ceiling plaster
CT = ceiling tile
DEM = dry erase materials

design = proximity to door
FC = food container
FCU = fan coil unit
G = gravity
GW = gypsum wallboard
M = mechanical

MT = missing ceiling tile
NC = non-carpeted
ND = non detect
PC = photocopier
PF = personal fan
plug-in = plug-in air freshener

PS = pencil shavings
sci. chem. = science chemicals
TB = tennis balls
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Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
600 - 800 ppm = acceptable
> 800 ppm = indicative of ventilation problems

Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

Leicester Primary School **Indoor Air Results**

170 Paxton Street Leicester, MA **Table 1** **June 10, 2004**

Location/ Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (*ppm)	Carbon Monoxide (*ppm)	TVOCs (*ppm)	PM2.5 (µg/m3)	Occupants in Room	Windows Openable	Ventilation Supply	Ventilation Exhaust	Remarks
105	76	55	1029	ND	ND	18	18	Y 2/3 Open	Y Univent	Y Ceiling	Carpet
106	75	53	848	ND	ND	11	18	Y 1/2 Open	Y Univent	Y Ceiling	Carpet
107	75	61	1827	ND	ND	17	17	Y	Y Univent	Y	PF, Food Use/ Storage, Carpet
108	74	52	629	ND	ND	10	8	Y 2/3 Open	Y Univent	Y Ceiling	TB Carpet
Computer	72	35	830	ND	ND	10	0	Y	Y Univent	Y Ceiling	25 Computers
201	79	46	628	ND	ND	9	1	Y 3/3 Open	Y Univent	Y Closet	
202	76	42	682	ND	ND	6	19	Y 3/3 0pen	Y Univent	Y Ceiling	CD
203	79	50	871	ND	ND	8	18	Y 2/3 Open	Y Univent	Y Ceiling	-

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204	79	49	1000	ND	ND	6	24	Y 3/8 Open	Y Univent	Y Ceiling	DEM
205	79	47	625	ND	ND	4	2	Y 2/3 Open	Y Univent	Y Ceiling	Plants, DEM
206	78	52	649	ND	ND	3	1	Y 3/3 Open	Y Univent	Y Ceiling	
207	79	53	943	ND	ND	4	21	Y 2/3 Open	Y Univent	Y Ceiling	DEM, PF, Clutter, Food Use/ Storage
208	78	47	564	ND	ND	4	15	Y 3/3 0pen	Y Univent	Y Closet	DEM, PF, Food Use /Storage
209	79	50	895	ND	ND	5	16	Y 2/3 Open	Y Univent	Y Ceiling	
210	78	46	495	ND	ND	5	1	Y 3/3 Open	Y Univent	Y Ceiling	PF, Clutter, Food Use / Storage

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211	78	48	945	ND	ND	11	24	Y 2/3 Open	Y Univent	Y Ceiling	CD, Food Use / Storage
212	79	47	700	ND	ND	6	1	Y 2/3 Open	Y Univent	Y	
K4	75	56	656	ND	ND	6	1	Y	Y Univent	Y Ceiling	Clutter, Seasonal Supply: window mounted AC
SPED 1	82	48	742	ND	ND	4	0	N	N	N	PF, Door Vent Doors Open: Hallway
SPED 2	82	49	662	ND	ND	8	1	N	N	N	Door Vent Doors Open: Hallway
K-2	75	55	774	ND	ND	7	17	Y 2/3 Open	Y	Y	CO, DN
K1	75	54	737	ND	ND	12	18	Y 4/4 Open	Y Univent	Y	PF, Cleaners

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Leicester Primary School | **Indoor Air Results**

170 Paxton Street Leicester, MA | **June 10, 2004**

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110	74	56	ND	ND	ND	9	19	N	Y Univent	Y Ceiling	
Pre School 2	75	55	700	ND	ND	5	3	Y 2/3 Open	Y Univent	Y Ceiling	Carpet, aqua./terra, clutter, Blocked: furniture Seasonal Supply: window mounted AC
K2	75	54	717	ND	ND	11	18	Y	Y Univent	Y	Carpet, PF
K4	75	56	656	ND	ND	6	1	Y	Y Univent	Y Ceiling	Clutter Seasonal Supply: window mounted AC
GYM	74	53	628	ND	ND	9	20	N	Y Wall	Y Wall	

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Appendix A

The following is a status report of action(s) taken on previous BEHA recommendations (**in bold**) based on reports from building staff, documents, photographs and BEHA staff observations.

1. **Examine univents in kindergarten classroom 4 and in the cafeteria for function, replace parts and make repairs as necessary. Operate univents while areas are occupied.**

   Action Taken: Univents were repaired and operating in these areas.

2. **Continue with plans to install new roof. Replace ceiling tiles and disinfect areas of water leaks as needed.**

   Action Taken: New roof was installed. Classroom were free of water damaged ceiling tiles.

3. **Store chemicals and cleaning products properly and out of the reach of students.**

   Action Taken: Some classrooms continue to be blocked with obstructions (see Tables).

4. **Increase/improve carpet cleaning in classrooms. Continue with plans to obtain a HEPA filtered vacuum cleaner.**

   Action Taken: HEPA filter vacuum obtained.